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Recovery from Gz-Induced Loss of Consciousness: Psychophysiologic Considerations

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Eight healthy male volunteer members of the USAFSAM acceleration panel were exposed to two consecutive acceleration runs of +1 Gz to +7 Gz at 6 G/s onset rates. The subjects were instructed to relax during the acceleration exposure in order to voluntarily induce loss of consciousness (LOC). The subjects were asked to relate dreams, thoughts, or other mental illusions experienced during G-LOC episodes. Most subjects were amused and surprised, as well as interested in, relating their experience, although they were embarrassed about the G-LOC episode itself. Early post-G-LOC transient paralysis, as well as late LOC myoclonic (flailing) movements, were evident. Heart-rate response to the acceleratory stress was uneventful; maximum heart rate occurred 3.2 s after the onset of LOC. The study of dreams during normal sleep stages has been reviewed by many investigators, but this research has not extended to acceleration/hypoxic types of unconsciousness where dreams also seem to occur. G-LOC dream-state analysis, post-G-LOC paralysis, and their possible repercussions upon performance and incapacitation periods should be investigated, not only as curious events, but as operationally important and psychophysiologically significant.

ACCELERATION-INDUCED LOSS of consciousness (G-LOC) has become highly significant in the study of aerospace medicine. Unfortunately, the psychophysiological consequences of a G-LOC episode have not been as fully investigated. This study concentrates on the dream-like event and other visual illusions that human subjects have experienced during G-LOC. The physiological aspects under consideration include heart-rate response to G-LOC and immediate post-G-LOC transient paralysis. The operational aspects of G-LOC have been previously reported (36).

METHODS

Eight healthy male volunteers (age = 31 ± 7, weight = 168 ± 22 lbs, height = 70 ± 3 in), members of the USAFSAM human centrifuge panel were exposed to two consecutive acceleration runs of +1 G_z to +7 G_z at 6 $G \cdot s^{-1}$ onset rates. The subjects were requested to relax during the acceleration exposure in order to induce voluntary G-LOC (straining maneuvers were not performed and a standard USAF anti-G suit was not worn). A tracking task, using a television screen and an F-16A stick, was to be performed before and after the acceleration exposures. Electrocardiographic response to the acceleration stress was obtained via sternal and biaxillary leads in order to medically monitor the subjects under study (29). Auditory (85 db) and visual warning signals were activated as soon as LOC was apparent. Before the acceleration exposure, the subjects were instructed to deactivate these signals as they recovered consciousness (CS). The subjects' reaction time and speed of recovery from unconsciousness were then determined (34). Acceleratory stress was terminated promptly after the subject lost CS, reducing centrifugal stress to an alternating 1- or 2-G_z level (36).

The eight subjects were aware of the possible request to relate their dreams, thoughts, or other mental illusions (if any) experienced during the G-LOC episode. These reports were collected on a tape recorder as soon as the subject terminated the assigned performance tasks; oral questions were posed to the subject to prompt and facilitate recollection of his mental state while he was unconscious. Written reports were also obtained where the subject recounted any further recollections of his experience. Some subjects were able to

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estimate their dream/thought time-span (ET), whenever applicable, as shown in Table I, compared to the observed period of unconsciousness (absolute incapacitation (AI)), which is the epoch where the investigators estimated a dream or thought might occur. "Dream" is defined in this paper as any coherent and detailed visual illusion described by the subjects as a dream comparable to that experienced during normal sleep. We do not attempt to equate G-LOC "dreams" to "normal sleep" dreams. However, their similarity is interesting and, for discussion purposes, we labeled these illusions "dreams." The technique to measure G-LOC incapacitation times has been described (34). Electroencephalogram (EEG) and electrooculogram (EOG) recordings were used to define the subject's unconscious state and rapid eye movement (REM) during such states, when applicable (24).

The electrocardiographic parameters analyzed were: resting heart rate (RHR) prior to $+G_z$ exposure, maximum heart rate reached throughout the run (MHR), the change in HR from rest to maximum (△HRB), and HR achieved at the onset of maximum $+G_z$ (HRA), the change in HR (△HRA) from rest to the onset of peak $+G_z$, the HR at G-LOC onset (HRU), and HR upon reaching recovery $+G_z$ level (HRR), the lowest HR achieved during recovery (HRL), and the steady HR established once recovery was "complete" (HRS). All measurements were accomplished manually (R-R intervals). Student's t-test was used for the analyses of these parameters (Fig. 1).

RESULTS AND DISCUSSION

A total of five dreams were recalled out of 21 acceleration runs (14 LOC episodes; 7 "black-outs") from eight subjects (two consecutive acceleration runs per subject). Subject 7 was exposed to the experimental protocol twice (the first set of exposures was treated as a preliminary protocol test and was included for discussion purposes only), and subject 3 underwent three consecutive exposures. Subject 8 did not experience G-LOC. A single thought process was reported by one subject (S2) who perceived his experience not as a dream per se, but as a wish to sleep and be "left alone, not wanting to be awakened" by the auditory stimulus which was routinely activated as soon as the subject lost consciousness (34). All three dreamers reported that their dreams were experienced during their first LOC episodes. Only one of these subjects (S3) recalled his second G-LOC-induced dream event, indicating that if any thoughts or dreams occurred during the second consecutive G-LOC episode, the subjects may have been mentally fatigued or psychologically altered and, therefore, dream/thought recall was not as easily achieved.

"Dreamers" were convinced that their mental experience was definitely a "dream" as opposed to a "thought." That is, their dreams were vivid and very intense as opposed to a drowsy mental state similar to the random thoughts usually experienced immediately prior to normal sleep.

At this time, it is difficult objectively to determine

TABLE I. G-LOC AND ASSOCIATED DREAM DESCRIPTION.

Subject	Run	Episode[a]	Experience	Dream Trend	REM	Flail	ET[b]	AI[c]
1	1	LOC			N	Y		12
	2	LOC			Y	Y		11
2	1	LOC	Thought	II	N	Y		10
	2	LOC			N	Y		12
3	1	B.O.			N	N		—
	2	LOC	Dream	II	Y*	Y	5	17
	3	LOC	Dream	II	N	Y	5	8
4	1	B.O.			N	N		1
	2	LOC			N	N		8
5	1	LOC			N	Y		<14
	2	LOC			?*	Y		<13
6	1	LOC	Dream	I	Y*	Y	5	27
	2	LOC			N	N		13
7A	1	B.O.			N	N		—
	2	B.O.			N	N		—
	3	B.O.			N	N		—
	4	LOC	Dream	I	?*	Y	15	4
7B	1	LOC	Dream	I	N	Y		14
	2	LOC			N	Y		13
8	1	B.O.			—	—		—
	2	B.O.			—	—		—

[a] LOC = G-induced loss of consciousness
[b] ET = estimated dream/thought time span in seconds.
[c] AI = absolute incapacitation period in seconds.
* = post G-LOC transient paralysis
? = could not determine with reasonable accuracy.
B.O. = black out (loss of vision prior to LOC).

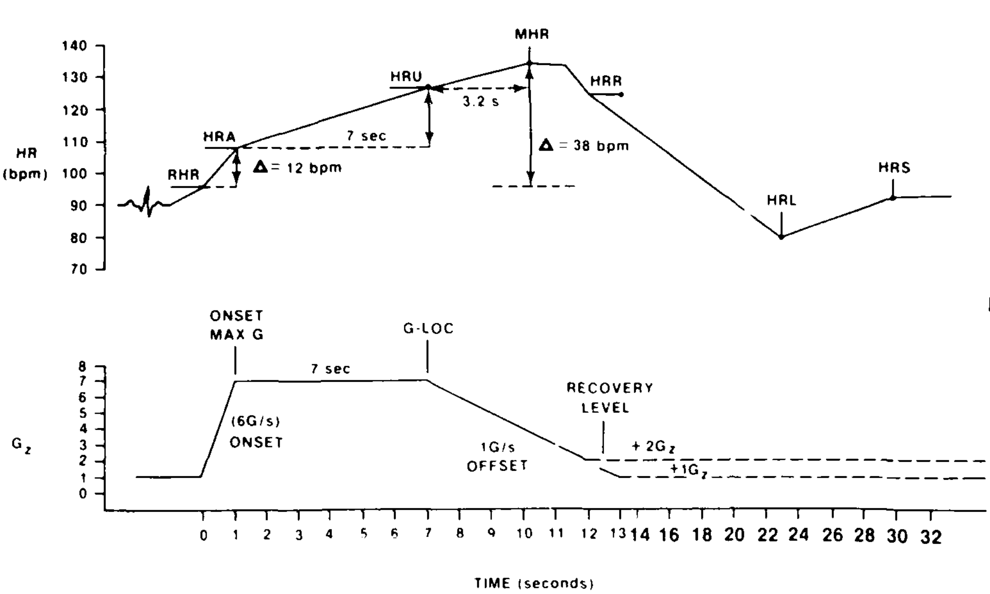

Fig. 1. Description of heart rate parameters.

exactly what the subjects experienced during their individual G-LOC episodes (dream or thought) or even state that G-LOC can be equated to a normal sleep mental state (in relation to dream activity). According to the EOG data obtained, the majority of the acceleration runs that involved an LOC episode did not show REM-like activity during unconsciousness. Three of these runs resulted in a dream (reported) during this period. These data indicate that G-LOC seems to result in "non-REM" dreaming. Although dreaming has traditionally been considered to occur during REM sleep, non-REM dreaming has been confirmed by other workers (9,13,25). Fig. 2 depicts a typical G-LOC exposure (S1).

All subjects were cooperative in the recollection of their unconscious episode. They were usually amused and surprised as well as interested in relating their experience, although they were frequently embarrassed by the LOC episode itself. The psychologic state of subjects suffering from recurrent G-LOC episodes has been reported (14,35).

There was some apparent REM-like activity (N = 3) during early recovery from LOC. This activity might be associated with the sense of paralysis that some subjects (N = 4) described as they justified why they could not turn "off" the visual or auditory stimuli previously mentioned; "I was paralyzed and slumped over . . . I could not turn 'off' the beep." These symptoms present a striking similarity to narcolepsy symptoms (temporary limbic paralyses/sleep paralyses, abrupt onset REM activity, and hypnagogic hallucinations). REM activity during narcoleptic episodes is usually present at the onset of the attack (4,23), but it is also known to occur near the end of such attack (4,11,26,28,32). Sleep paralysis is not always identified with narcolepsy; 5% of the normal population experience this type of attack where the individual is unable "to perform voluntary movements occurring at the onset of sleep or upon awakening during the night or in the morning" (2,15,20,21,30,37). Broughton, *et al.* (2,12) state: "In sleep paralysis, the subject either awakens paralyzed during the initial pe-

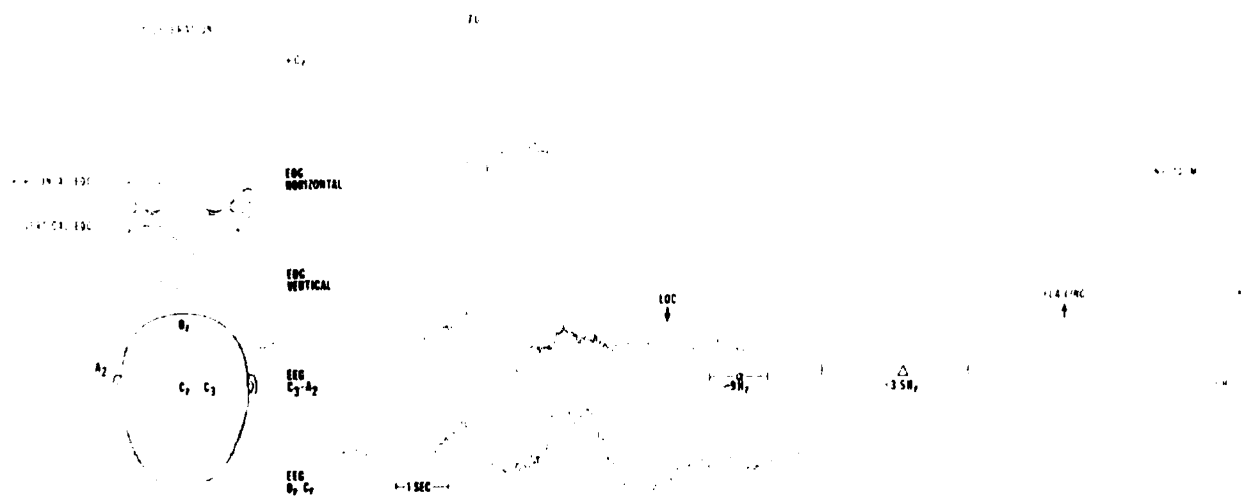

Fig. 2. EEG and EOG description (S1).

riod of falling asleep or during arousal later in the night. In either case awakening is from REM sleep, i.e., either a sleep onset REM period or a later REM period." The EEG and EOG data were used to determine a definite state of unconsciousness during the acceleration exposures. EEG analysis demonstrated a shift from beta to delta activity with pronounced absence of beta activity during unconsciousness (16). Visual analysis was considered adequate for our purposes. Fig. 3 depicts an apparent G-LOC episode. Unfortunately, electromyogram recordings were not available for this study.

Sleep paralysis has been identified as early as 1876 and described as an event where the motor centers are " 'asleep' while 'consciousness' is awake" (15,17,31). That is, the victims of sleep paralysis are consciously aware of their surroundings but are unable to move. This paralysis may last a few seconds or minutes. It is possible then, that the stimulus (mainly auditory) used in this study to arouse the subject undergoing syncope caused the "sleeper" to wake up before the "appropriate" time. Consequently, post-LOC transient paralysis occurred, rendering the subject unable to deactivate the warning signals immediately upon recovery, as he was instructed. That is, motor and mental processes were not concurrently stimulated. Schneck, *et al.* (17,27) have stated that "the victim may be released from sleep paralysis by outside interference that varies from a light touch to rigorous shaking." This is not to say that an auditory stimulus is not a vital device to rouse G-LOC victims from their syncopal state, but that it is a possible explanation for the occasional post G-LOC transient paralysis episodes reported by individuals that have experienced it. Vanderheide, *et al.* (33) suggested that sleep paralysis was related to "a state of confusion as to emotion and intention, with resulting indecisiveness." This statement clearly describes the symptoms observed in the subjects as they recovered consciousness; the subjects could hear the auditory stimulus and see the master caution light but, even though particularly eager to turn them "off," they were "unable" to do so.

Apparent transient paralysis has also been known to occur during flight as pilots awaken from episodic loss of consciousness (10,18,22). Post G-LOC transient paralysis has not been properly documented since the episode is so short (2-5 s) and probably not reported due to either amnesia or embarrassment (35). At this time it is not possible to equate sleep paralysis with post-G-LOC paralysis, but their similarities should be considered in the study of G-LOC.

Currently, it is difficult to ascertain whether the "dreams" reported were either "hypnagogic" (as the subject loses CS) or "hypnopompic" (as the subject regains CS), since the period of absolute incapacitation was extremely short (12.6 ± 5 s) and there was no capability of awakening the subjects immediately after REM-like activity (if any) was apparent during their period of unconsciousness (Fig. 4). As mentioned earlier, dream reports were not obtained until after the assigned performance tasks were accomplished (approximately 6 min) once the subject had recovered from G-LOC. Therefore, dream recall was not optimal for determination of a specific point in time where the dream might have occurred during unconsciousness (13,19,38). However, it is interesting that a coherent visual illusion can be generated in such a short time.

Two trends were apparent in the nature of the dreams reported: Trend I—subjects experienced confusion/anxiety, frustration, a sense of "paralysis" with the dream set in enclosed spaces such as a closet or small room ("I was in a dark closet, I was in a dark closet, and there was a red light at the very top . . . the closet was square, small and empty . . . I was confused but unafraid"); Trend II—subjects were generally happ (euphoric), relaxed, their dreams were generally set open areas during daylight and were colorful ("I was outdoors looking at the sunset, it was a fall sunset; red-orange, I was happy"). All the reported dream episodes were related to the specific individual's recent activities or preoccupations as considered typical by other workers (1,6). The trends specified previously are based on the subjects' descriptions of their dream events and observation of the subjects' reactions to these events and the G-LOC episode itself. This classification may be useful to determine/predict performance upon regaining consciousness. That is, the dream content (pleasant vs.

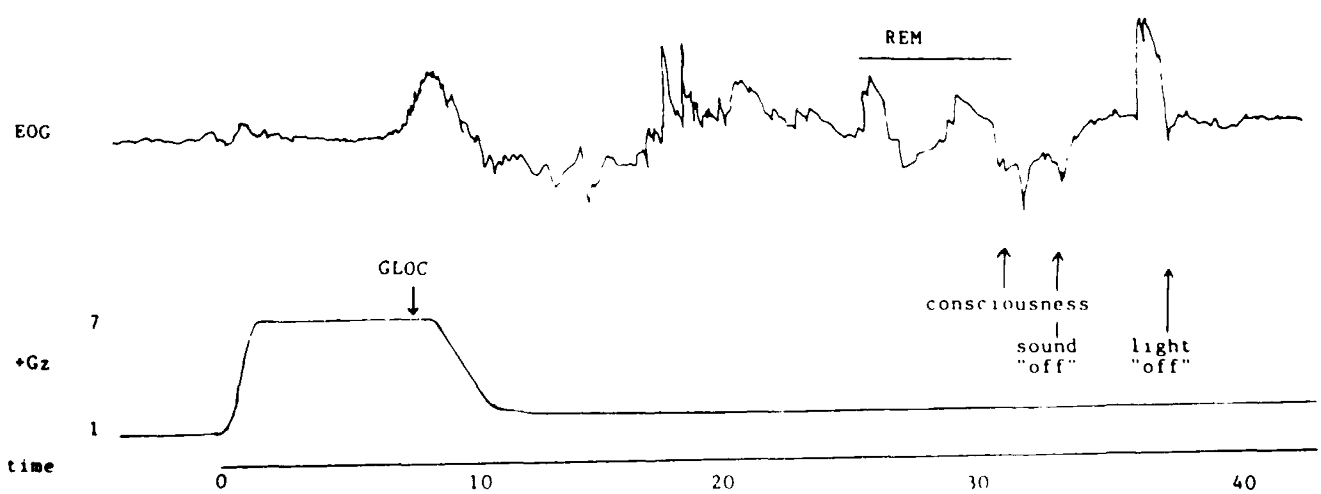

Fig. 3. Apparent late G-LOC REM episode.

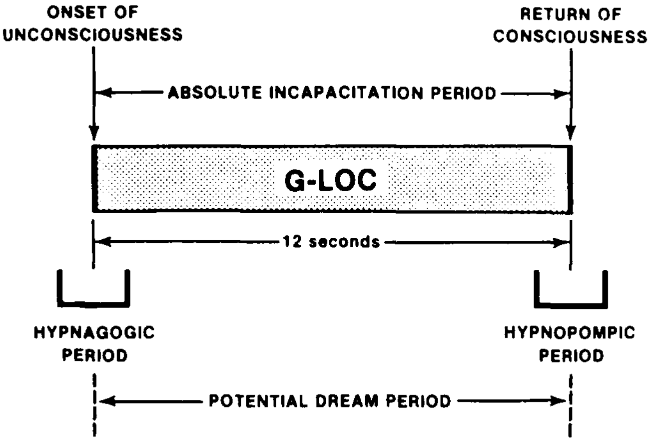

Fig. 4. Description of G-LOC-DREAM period.

unpleasant) might influence the period of confusion that follows a G-LOC episode and the general state of mind of the individual recovering from syncope (3).

The subjective estimate of the dream/thought time span (ET) did not reveal an evident correlation with the unconscious (AI) period. However, there was a tendency for the subjects to underestimate the length of their unconscious episode.

While most of the subjects ($N = 6$) experienced evident myoclonic (flailing) movements during the G-LOC episode (it should be emphasized that urinary or bowel incontinence has not been observed in any of the G-LOC episodes at USAFSAM), it was not possible to determine if these peribuccal and/or myoclonic (usually the upper extremities) movements were related to the subjects' dream states at the time of absolute incapacitation. Insofar as the dream content is concerned, no sign of activity was reported. However, this fact does not preclude the possibility of correlation between dream content and physical movement while dreaming (whether the dream content provokes physical movement or vice versa is a continuous argument among experts) (5). Other G-LOC episodes that have been recorded do seem to indicate a relationship between the dream content and physical state*. It is more likely that, in this study, the observed flailing movements during the subject's LOC episode were attributable to acceleration-induced hypoxia resulting in central nervous system dysfunction, rather than to dream content. Determination of when G-LOC-induced dreams occur and the specific anatomic area(s) responsible for the dream may provide a strategy for incapacitation reduction and G-LOC prevention. Further research of dream-like events occurring during G-LOC and the apparent transient paralysis associated with this episode is necessary. Currently, it is difficult to obtain EEG data in the acceleration environment. However, current studies are attempting to successfully correlate EEG, EOG, and EMG parameters with G-LOC and associated dream-like events.

Heart-rate response to the acceleration stress did not show any unexpected results (Table II). Maximum heart rate occurred 2.9–3.5 s after G-LOC onset, and stabilized in a normal manner as $+G_z$ was reduced to $+1\ G_z$ or $+2\ G_z$. The resting heart rate was elevated, probably due to the anticipated $+G_z$ stress and G-LOC, but was not significantly different from comparable $+G_z$ exposures that did not involve a G-LOC episode. The mean maximum heart rate (MHR) of the G-LOC exposures was significantly lower ($p<0.05$) than that for analogous non-G-LOC exposures (8). However, the mean time of exposure to peak $+G_z$ level before G-LOC was 7 (± 2) s, whereas non-G-LOC exposures with comparable $+G_z$ level and onset rate ($+7\ G_z$, $6\ G \cdot s^{-1}$), usually involve an exposure to maximum G level for 15 s or longer. There was no significant difference in the recovery heart rates of $+1\ G_z$ and $+2\ G_z$ (Fig. 1).

CONCLUSIONS

The study of dreams during normal sleep stages has been thoroughly reviewed by many investigators (1,6,9,15,25,38). Unfortunately, this research has not extended to acceleration/hypoxic types of unconsciousness where "dreams" are also evident. Although dreams have always been an intriguing subject and, to some, a psychological panacea, the dream experienced during G-LOC could better define the psychophysiologic state of mind of the aircrewmember. The mental illusion experienced may therefore allow more indepth understanding of the unconscious state and the individual's post-G-LOC performance relative to his previous state of consciousness (i.e., an individual might perform

* Forster EM, Whinnery JM. Dream occurrence during transient acceleration-reduced loss of consciousness (manuscript in preparation).

TABLE II. MEAN HEART RATE RESPONSE (bpm) TO G-LOC*.

Abbrev	Parameter	Mean HR (S.D.)
RHR	Resting heart rate	96 (16)
HRA	HR upon reaching maximum $+G_z$	108 (14)
ΔHRA	Change in HR: resting to onset of max $+G_z$	12 (7)
HRU	HR at onset of G-LOC	126 (12)
MHR	Maximum HR during the $+G_z$ exposure	134 (13)
ΔHRB	Change in HR: rest to maximum	38 (11)
HRR	HR upon reaching recovery $+G_z$ level	125 (16)
HRL	Lowest HR reached during recovery	80 (21)
HRS	Steady HR established-complete recovery	92 (12)

* = pooled 1 and 2 $+G_z$ recovery data.

more adequately if his unconsciousness-dream-event was pleasant rather than repulsive), determine the individual's state of mind as he/she recovers from unconsciousness and potentially create new and more effective modes of arousal from unconscious states (i.e., simultaneous stimulation of G-LOC victims motor and mental processes). Therefore, G-LOC dream-state analysis, post-G-LOC transient paralysis, and their possible repercussions upon performance and incapacitation periods should be investigated not only as a curious event but also as operationally important and psychophysiologically significant.

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